R&D Projects with High Current Ion Sources

A. Adonin and R. Hollinger

GSI, Darmstadt, Germany.

Development of high current Au and Pb beams for experiments on SIS

As was reported previously [1,2], to enlarge the number of elements for acceleration and to fulfill the requests of several research projects at GSI the program of developing of further heavy elements for acceleration has been established. In the frame of this program the development of three additional elements: ^{197}Au, ^{208}Pb and ^{209}Bi for operation with the VARIS ion source was foreseen.

Challenges and Solution

Due to the requirements of HSI RFQ (the mass-over-charge ratio should not exceed 65) the requested charge state of ions for considered heavy elements is 4^+. It is challenging to produce a sufficient amount of four-fold ions in the plasma generated by vacuum arc discharge in the VARIS ion source, because of the physical properties of these elements. Rapidly increased flux of neutrals from a cathode surface during the discharge pulse shifts the charge state distribution of ions in the plasma to lower charge states (maximum at 1^+, 2^+) for the time of about 50 µs after ignition of the vacuum arc. As was confirmed experimentally [3], due to this effect it is not possible to provide stable high current operation of Au, Pb and Bi beams using the cathode made of pure materials. But the situation can be dramatically improved by using composite materials in cathodes with admixing of certain amount of more refractory metals.

Investigation of various Au-alloys

Proceed from the phase diagrams of different Au-Metal binary systems, the following metals were chosen for admixing to Au: Pd, Cr, Zr, Ti and Ta. First cathode sets were manufactured containing small amount of admixed material (between 5 % and 20 % wt.) After the first experiments the most promising results were achieved with Au-Cr (20 %) and Au-Zr (20 %) cathodes.

The composite cathodes required quite long conditioning time (more than 10 hours of operation with 1 Hz) before they could provide high current stable beam of Au^{4+}. The investigation of the surface and the material structure of the Au-Cr cathodes using optical and electron microscopes has shown appreciably higher concentration of Cr on the working surfaces of good conditioned cathodes (Fig.1). Considering this fact next tests (in February 2012) were performed with Au-Cr (50 % wt.) and Au-Cr (75 % wt.) cathodes. Manufacturing of Au-Zr cathodes with higher Zr percentage was not successful due to particular chemical properties of Zr. The cathodes from Au-Cr (50 %) material showed much better performance than others. After short (10-20 min) conditioning time they provided stable beam of Au^{4+} ions with beam currents up to 6 mA in front of the RFQ, proper beam pulse shape and good pulse-to-pulse repetition. The typical duty cycle was 1 Hz with 300 µs pulse length. The charge state distribution of Au ions was: 14 % of 2^+, 44 % of 3^+, 38 % of 4^+ and about 4 % of 5^+. The Cr-fraction in the ion spectrum was more than 50 % with maximum at 3^+. Since Au^{4+} and Cr^{1+} ions stay by ***A/Q*** ratio relatively close to each other, a variable slit behind the dipole magnet was used to cut Cr^{1+} ions. The high current ^{197}Au-beam was successfully provided for HADES experiment in April-May 2012 (5 weeks of beamtime).

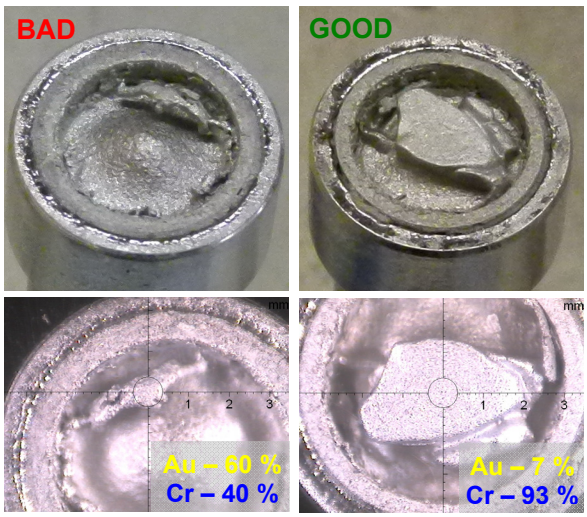

Figure 1: Au-Cr (20 % wt.) cathodes after 1 day of operation: bad performance (*left*) and good performance (*right*).

Investigation of Pb-Cu alloys

The first tests with Pb were performed in June 2012 using composite Pb-Cu cathodes with various amounts of Cu admixed (40 % and 60 %) and different manufacturing techniques (powder metallurgical and infiltration). The best performance has been shown by Pb-Cu (40 % wt.) infiltrated cathodes. They provided stable operation with good pulse-to-pulse repetition and beam currents up to 6 mA in front of the RFQ. However all cathodes required relatively long conditioning time (more than 3 hours with 1 Hz operation). The charge state distribution of Pb-ions was: 30 % of 3^+, 63 % of 4^+ and 7 % of 5^+. The ^{208}Pb-beam was successfully provided for FRS experiments in September-October 2012 (2 weeks of beamtime).

References

[1] A. Adonin et al., GSI Scientific Report 2010.
[2] K. Tinschert et al., GSI Scientific Report 2011.
[3] A. Adonin and R. Hollinger, Proceedings of the 25th ISDEIV, Vol.2, p.630, Tomsk, Russia, Sep. 2012.